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OPERATION CONTROL SYSTEM FOR AIRCRAFT

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16. Abstract

A description is given of a German patent used for operational monitoring for aircraft, using the multiplex method of a large number of measurement transducers, producing the measured variables in the form of electrical output signals.

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Documents used to evaluate the patent characteristics:

DT-PS 837-476
DT-AS 1 103 189
DT-AS 1 210 576
US-PS 2 611 811

Electrical Measurement of Non-electrical Quantities (1962). p. 55

OPERATION CONTROL SYSTEM FOR AIRCRAFT

K. Busch and H. Bruemmer

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PATENT CLAIMS:

1. Operational monitoring system for aircraft for multiple use of communication paths using the multiplex method with a large number of measurement transducers, which produce the measured variables in the form of electrical output signals. With them, assigned display devices are activated which are characterized by the following combination of well-known characteristics:

a) The measurement transducers (1) have standardization units (2) switched after them;
b) There is a cyclically rotating first scanning unit (3) connected to the standardization units.
c) There is an analog-digital converter (4) switched in after the first scanning unit (3).
d) The output of the analog-digital converter (4) is connected with a second scanning unit (5) which rotates synchronously with the first scanning unit (3) through a transmission line (9);
e) There are quasi-analog solid state display units (8) connected to the outputs of the second scanning unit (5).

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* Numbers in margin refer to the column numbers in German patent.

2. Operational monitoring system according to Claim 1 characterized by the fact that numerical solid state display units can also be connected in addition to the quasi-analog solid state display units.

3. Operational monitoring system according to Claims 1 and 2 characterized by the fact that the first scanning unit (3) also covers additional measured values which have already been converted to digital form. These are ordered into the output signal sequence of the analog-digital converter (4) through a matching circuit (7).

4. Operational monitoring system according to Claims 1 and 3 characterized by the fact that the first scanning unit (3) and the analog-digital converter (4) are located in the vicinity of the measurement points, and the second scanning unit (5) is located in the vicinity of the display units (8).

5. Operational monitoring system according to one of the Claims 1 to 4 characterized by the fact that storage units are assigned to the display units (8) which fix the measured values between sequential scannings.

6. Operational monitoring system according to one of the Claims 1 to 5 characterized by the fact that between the first scanning unit (3) and the second scanning unit (5) there is at least one digital computer (14, 24, 25).

7. Operational monitoring system according to Claim 6 characterized by the fact that the computer (14, 24, 25) collects preselected combinations of measured values into replacement variables.

8. Operational monitoring system according to Claim 6 or 7, characterized by the fact that there is an alarm device (16) connected to the computer (14, 24, 25) which is activated when certain measured values or measured value combinations exceed a prescribed tolerance.

9. Operational monitoring system according to one of the Claims 6 to 8, characterized by the fact that the computer (14, 24, 25) only displays preselected measured values when preselected critical limiting values are reached.

10. Operational monitoring system according to one of the Claims 6 to 9 for simultaneous monitoring of several engines, characterized by the fact that a special engine computer (24) is assigned to each engine. /2

11. Operational monitoring system according to Claim 10 characterized by the fact that a central digital computer (25) collects preselected output variables of the individual engine computers (24) to form replacement variables.

12. Operational monitoring system according to one of Claims 6 to 11, characterized by the fact that a recorder (17) is connected to the computer (14, 24, 25) which records preselected output variables of the computer.

The invention involves an operational monitoring system for aircraft for multiple exploitation of communication paths using the multiplex method with a large number of measurement transducers, which convert the measured quantities into the form of electrical output signals, which are then used to operate the assigned display units.

The operation of the onboard installations in modern aircraft requires continuous monitoring both during flight, take-off and landing, in order to provide orderly and accident-free flight conditions. In addition to the navigational installations, it is necessary to monitor the engines and their accessory units, the control surfaces and the landing gear. In addition, a multiplicity of physical-technical variables must be displayed to the pilot either continuously or from time to time. As the performance of aircraft increases as well as their engines, it becomes more and more necessary to subject the materials of the engine and the airplane to loads close to the load limits. In this way, the importance of a measurement and monitoring installation increases as well as the requirements for accuracy and reliability. This is necessary in order to reliably determine the separation between actual loads and load limits. At the same time, the number of processes which have to be monitored as well as the operational states have increased, so that the observation of the instruments which indicate these states burdens the attentiveness of the pilot to an ever-increasing degree.

The measured value display up to the present time was done in an analog manner in most cases; in some cases there was digital read-out. Two types of units were used for analog displays. The first type are display instruments such as membrane measurement units, rotating coil and crossed coil units and synchronous or rotating field systems which are connected to the transducer either directly or through a signal amplifier. These are mechanically simple but are relatively inaccurate and are sensitive to vibration. The other type are servo driven measurement units, in which a display servo motor is driven through a follower controller. These measurement units have relatively high accuracy but are heavy, large and expensive and have a large power requirement. The combination of the known instrument types leads to a confusing multiplicity in the cockpit of modern aircraft, which is underlined even more by the differences in scale design, type of measured value display, etc.

The measurement transducers used in known systems convert the physical measured variables, for example a pressure, a temperature or a torque, into a measured value signal, for example, a mechanical path, the expansion of a liquid or an electrical signal. Accordingly, in the known monitoring systems, we find different display units as well as different types of transmission devices for transmitting the measured signal from the measurement transducer to the display unit: for example, mechanical linkages, pressure lines and electrical cables. The weight of aircraft is very important in modern aircraft technology, especially for vertical takeoff aircraft. If one considers a closed monitoring system, we find that the weight of the measurement transmission devices is often many times the weight of the display unit or of the measurement transducer. Consequently, in order to optimize a monitoring system, it is necessary to consider the entire measurement chain consisting of the measurement transducer, communication system and display unit. /3

It is already known that in order to transmit electrical measured values, it is possible to use various multiplex methods, so that communication paths can be used several times which makes possible an optimization of the communication installation. The time multiplex method has been found to be especially suitable for the application discussed here, in which the pulses of certain measurements are transmitted in the time gaps which occur between pulses which follow one another. The reliability of the transmission is high, because these measured values are transmitted in digital form. Devices which operate according to this method include a cyclical scanning unit on the measurement transducer side and on the display side, which are connected through a line. The measurement transducers which provide analog values are connected to the scanning units through analog-digital converters or they are connected to display units which respond to analog values through digital-analog converters, and the digital measurement values or display units are directly connected. Since most of the measured values are produced in analog form, and in general an analog display is desired, a considerable number of converters are necessary in these installations, so that the weight and construction volume advantage gained by the small number of transmission lines is again eliminated by the weight and volume of the large number of components.

In addition, in order to determine mechanical loads, i.e., of aircraft propellers during test series, we know of an installation which has measurement bridges containing several electrical measurement transducers. Their outputs are switched in parallel and are connected with a display unit in the form of an oscillograph through an amplifier. The inputs of the measurement bridges are given according to a time sequence either by a special pulse generator or by a single frequency-modulated oscillator through a filter. In such an installation, the transmission paths are also used several times and the associated advantages are exploited. The measurement values are transmitted in analog form, however, so that the reliability of transmission is unsatisfactory. In addition, only a single display unit, an oscillograph, is available, which is too heavy, inaccurate and subject to disturbances to be used for monitoring the operation of aircraft. Also it is impossible to install the various displays in the cockpit of the aircraft in a reasonable manner.

In addition, quasi-analog solid state display units are available which have a large number of scales which have been divided into parts, that is they have been quantized. The individual segments can be made to light up either individually or in a continuous sequence of selectable length, so that the changes can be made visible. Light bulbs can be used to light up the individual segments of the scale, such as is used to display the position of bodies moving along a linear trajectory . Also electroluminescence cells, light diodes, crystal or liquid cells, etc. can be used for this. Such a display unit can be controlled digitally and therefore has the advantage of all digital systems, i.e., it does not have to be calibrated and equalized and there is no 0. migration. The scale characteristic is linear and can be distorted in a simple manner. However, for the observer, the display is practically analog and therefore, at the same time, provides the advantages of analog displays, i.e., reading is simplified because a reference quantity is available in the form of a scale, the tendency of a measured value to change is clearly identifiable, and it is possible to compare measured values with a single look.

The purpose of the invention is to design an operational monitoring system for aircraft which has a high degree of technical maturity as far as ruggedness, reliability, accuracy, weight and construction volume are concerned. Also, it attempts to minimize the pilot stress associated with its use. This problem is solved according to the monitoring system discussed at the beginning using the following combination of known characteristics:

a) There are standardization units after each of the measurement transducers.
b) A first scanning unit which rotates in a cyclical manner is switched after the standardization units;
c) An analog-digital converter is switched in after the first scanning unit;
d) The output of the analog-digital converter is connected through a transmission line with a second scanning unit which rotates synchronously with the first scanning unit;

e) There are quasi-analog solid state display units connected to the outputs of the second scanning unit.

Because of the standarization of the output signals of the measurement transducers by the standardization units, various measurement transducers can be used for monitoring the various measured values. The signal transmission can be carried out using parallel-series converters using the time and frequency multiplex method, and the time multiplex method is to be preferred. In addition, in this way and by the use of quasi-analog display units, it becomes possible to use a single analog-digital converter for the entire system, which is switched in after the first scanning unit which rotates in a cyclical manner. This is not only important because of the total system weight and the construction volume, but also because of the overall complexity of the system, because the analog-digital converter determines the accuracy of the digital transmission system and consequently must satisfy stringent requirements.

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In this way, since the measured value transmission and processing are done in a digital manner, voltage changes and nonlinear areas practically play no role at all. Distortions can be easily compensated for and the reliability of the system is accordingly high. The power consumption is low. By using quasi-analog solid state display units, the display for the system is digital but essentially analog as far as the observer is concerned. By combining the characteristics mentioned above, we exploit the advantages of both digital and analog technology but we have essentially eliminated their disadvantages.

Another advantage of the operational monitoring system according to the invention consists of the fact that numerical displays are easily included in the quasi-analog display surfaces, i.e., in the case of round instruments, in the center, because the centers now no longer contain the pointer axis for the pointers. Solid state display units can also be used for numerical displays, and their individual parts can be arranged to display numerical or alpha-numerical symbols to form groups. The quasi-analog display can also be used to provide a clear rough display, whereas the numerical display makes possible the reading of exact measured values if necessary.

In another version of the invention, additional measured values which are already in digital form, are also processed by the first scanning unit and are ordered into the output signal sequence of the analog-digital converter after the analog-digital converter through a matching circuit.

The first scanning unit and the analog-digital converter should preferably be arranged in the vicinity of the measurement points (for example, the engine) and the second scanning unit should be located in the vicinity of the display unit (cockpit). In this way it becomes possible to transmit all of the measured values through a line, i.e., a high quality coaxial cable. It is no longer necessary to use the multiple line cables used in known systems containing between two to five lines for the display unit and the associated separation connectors, as well as possibly the individual amplifiers installed in the transmission channel.

In order to provide continuous reading, it is appropriate to assign storage units to the displays, which fix the measured values between sequential scans.

Up to the present, measured variables such as pressure, rotation rate, temperature or pressure and rotation rate ratios were displayed individually. The pilot then had to establish the quantities required for executing any flight task using the displayed units. For example, the thrust of the engines can be determined from the display parameters.

The operational monitoring system, which has available measured signal values in digital form, can be expanded in an especially advantageous way. Between the first scanning unit and the second scanning unit, at least one digital computer is installed. Such a computer can combine several measured value signals in a manner previously done by the pilot, i.e., the computer can calculate replacement variables from the individual parameters, which unburdens the pilot. The computer supports the pilot by making preliminary decisions. In addition, it can be part of the control loop with direct effect on the engine.

In most cases it will be sufficient to display only the replacement variables instead of the individual values. This integration of the individual displays leads to an information picture which is especially clear and can be rapidly evaluated. In general, it is advisable to let the computer establish whether tolerances in the individual parameters have been exceeded and to let the computer connect the alarm systems. These alarm systems are operated when such excesses occur. In this way, forbidden, nominal-actual deviations no longer go unnoticed, caused by the fact that the factors cancel under some conditions when the replacement variable is calculated.

A number of operational conditions only become interesting when they show unallowably large deviations from the nominal value. This monitoring can also be done by the computer. A central warning panel can be used to display the tolerance violations. This display can then be connected with a command to the pilot.

If several engines are present, a computer can be associated with each of the engines. The replacement variables determined by the engine computers can then be directed to a central digital computer. The central digital computer can be designed so that, in the case of a failure of an engine computer, it will partially or completely take over its functions and will also calculate data which gives information on all of the engines, for example, the total thrust, the sum of the fuel consumption of all engines, etc.

In addition, nominal value changes based on changed environmental conditions can also be calculated and therefore, new control variables and servo commands for the control loops can be determined (adapter system).

The operational monitoring system according to the invention also allows an additional important expansion in the direction of aircraft maintenance. Up to the present, engines, for example, turbines are overhauled after prescribed flight intervals or they are replaced. The allowable flight time is found from experience. Using this method, it is now possible to eliminate premature failures. Many times it would be possible to operate the turbine safely longer than the predetermined flight time. The reason for turbine or burbine-part failures are well known at the present time. Usually this is caused by thermal shocks, excessive rotation rate, bearing vibrations and blade oscillations. The operational monitoring system according to the invention makes it possible to determine the corresponding variables and the computer can evaluate their influence on the lifetime of the turbine. A recording unit can then be used to correct the evaluated variables, which is connected to the computer. These recordings will then provide valuable information to the maintenance crews about the true lifetime of the turbine or the remaining expected flight time.

It is appropriate to provide adequate redundancy for safety reasons. For example, the central transmission line, the analog-digital converter and other important central components or component groups can be made redundant, double or more. /7

Additional design features, advantages and application possibilities of the invention, are the result of sub-claims, which will be described according to the following versions explained by the drawings.

In the following we have:

Figure 1, a principal circuit diagram of an operational monitoring system according to the invention,

Figure 2, an expansion of the system according to Figure 1 and

Figure 3, a structural diagram of the new system with emergency circuits.

In Figure 1, we show only a single measurement transducer 1 for clarity. It is obvious that in practice there will be a large number of such measurement transducers. Two types of measured variables are determined when engines are monitored. On the one hand, we have first order measurement variables, which describe the changes of especially endangered components and which make it possible to obtain information on the safe operational lifetime of the turbine. Then we have second order measurement variables, which determine information required for optimum settings considering the flight condition. The oscillations of the turbine shaft, pressure of the critical compressor stage, combustion chamber temperature, turbine temperature, bending load of the compressor blades, radial gap in the compressor housing, fuel flow and fuel pressure are examples of first order measurement variables. The compressor rotation rate, air inlet temperature, afterburner temperature, fuel temperature, thrust, rotation rate and nozzle position angle are second order measurement variables.

In addition to the measurement recorder, the measurement transducer 1 includes a measured value converter, which transforms the measurement transducer output into an electrical output signal, unless the measurement recorder does not already provide an electrical output signal. There is a standardization unit 2 switched in after each measurement transducer 1, which standardizes the measurement quantity to a standard signal. The standardization units can be attenuators or amplifiers. Using the first standing unit 3, the standardized measurement variables are scanned cyclically and are directed to an analog-digital converter 4. The scanning unit 3, as well as the second scanning unit 5, is a rotating switch in principle, in which the mechanical contacts have been replaced by solid state components. There is a tact generator 6 provided for controlling the two scanning units 3 and 5. The measured variables appear at the output of the analog-digital converter 4 in a time sequence in the form of pulse groups, and the code depends on the design of the converter.

Measured values already available in digital form are also processed by the scanning unit 3 and are ordered into the pulse groups after the analog-digital converter 4 through a matching circuit 7. These pulses are then directed to the scanning unit 5 which operates synchronously with the scanning unit 3. The former then distributes them to the corresponding quasi-analog or numerical solid state display units 8, five of which are shown in Figure 1. The display unit 8 contains storage units, which fix the measured values between sequential scans. The scanning time is controlled by the encoding rate of the analog-digital converter 4. The scanning frequency is controlled by the signal frequency to be transmitted. The scanning frequency must be at least twice as high as the highest signal frequency being transmitted.

If the component group consisting of the scanning unit 3, analog-digital converter 4, tact generator 6 and matching circuit 7 is arranged in the vicinity of the measurement points, for example, the turbine and if the scanning unit 5 is arranged in the vicinity of the display instruments 8, then all of the measured values can be transmitted through a single transmission line 9, i.e., a coaxial table. In addition, we only need a synchronization line 10, which connects the tact generator 6 with the scanning unit 5 for transmitting the synchronization pulses.

Figure 2 shows an operating monitoring system in which there is a digital computer 14 between the first scanning unit 3 and the second scanning unit 5. The block diagram shows the information flow between the data sources, that is, the measurement transducer 1 and the manual input unit 15, on the one hand, and the data consumers in the form of display units 8, alarm panel 16 and recording unit 17 on the other hand. The following must be input manually: inputs for programming a system, fixed and limiting values, command list, nominal values, i.e., the setting of the gas pedal by the pilot. The quantities are input manually on a keyboard or with punched cards, etc.

The signals produced by the measurement transducers 1 are conditioned in the standardization units 2. Again it is assumed that some of the measurement transducers have digital and some have analog outputs. The signals are switched through a digital channel or an analog channel of the scanning unit 3, depending on signal type. The digital signals are sent directly to the digital computer 14, whereas the analog signals run through the analog-digital converter 4, who then passes on the signals in digital form to the computer 14.

The program control 18 does the following: switches the scanning unit 3 in scanning unit 5 synchronously, takes the fixed and limiting values from a storage unit 19, selects the computer program and distributes the computer results to the display units 8, the alarm panel 16, and the recording unit 17. The alarm panel 16 displays tolerance excesses. The evaluated measurement variables of first order are recorded in the recording unit 17. The digital computer 14 is also used as a member in the control loops. The actuater commands determined by the computer go to the actuater units 20.

Figure 3 shows a diagram of the structure of the new system in conjunction with emergency circuits using engine computer 24 associated with the individual engines and a central digital computer 25. The dashed lines are examples of emergency circuits if an engine computer 24 fails. The dash and dot lines represent an emergency circuit for failure of the analog-digital converter 4.

By using individual engine computers 24, we provide that each engine functions separately. The important control and display loops have a decentralized location in order to provide for the continued regulation of the turbine and adequate display in the case of a failure of the engine computer. Auxiliary /9
analog-digital converter 26 and digital controller 27 are used for this, which, for example, retain either the last set nominal value or an average nominal value independent of a control by the computer. Another possibility is to have the central computer 25 take over at least part of the tasks of the failed engine computer.

The analog-digital converter 4 has a reserve converter 28 switch in parallel according to Figure 3, which becomes operational when converter 4 fails.

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1 Sheet of Drawings

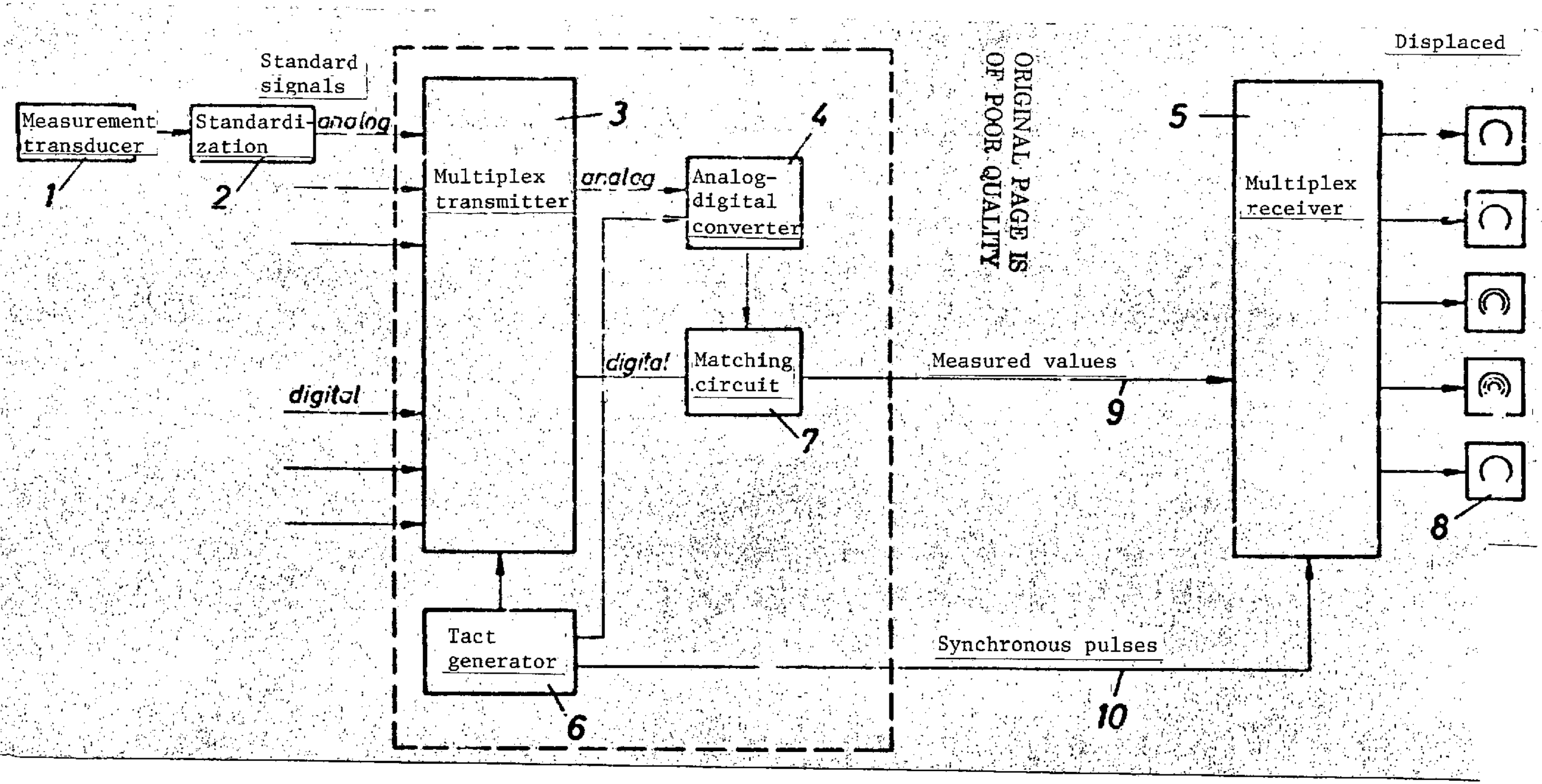
Standard signals
Measurement transducer
Standardi- zation
analog
1
2
3
Multiplex transmitter
analog
4
Analog- digital converter
digital
Matching circuit
7
digital
Tact generator
6
Measured values
9
Synchronous pulses
10
5
Multiplex receiver
Displaced
8

Figure 1.

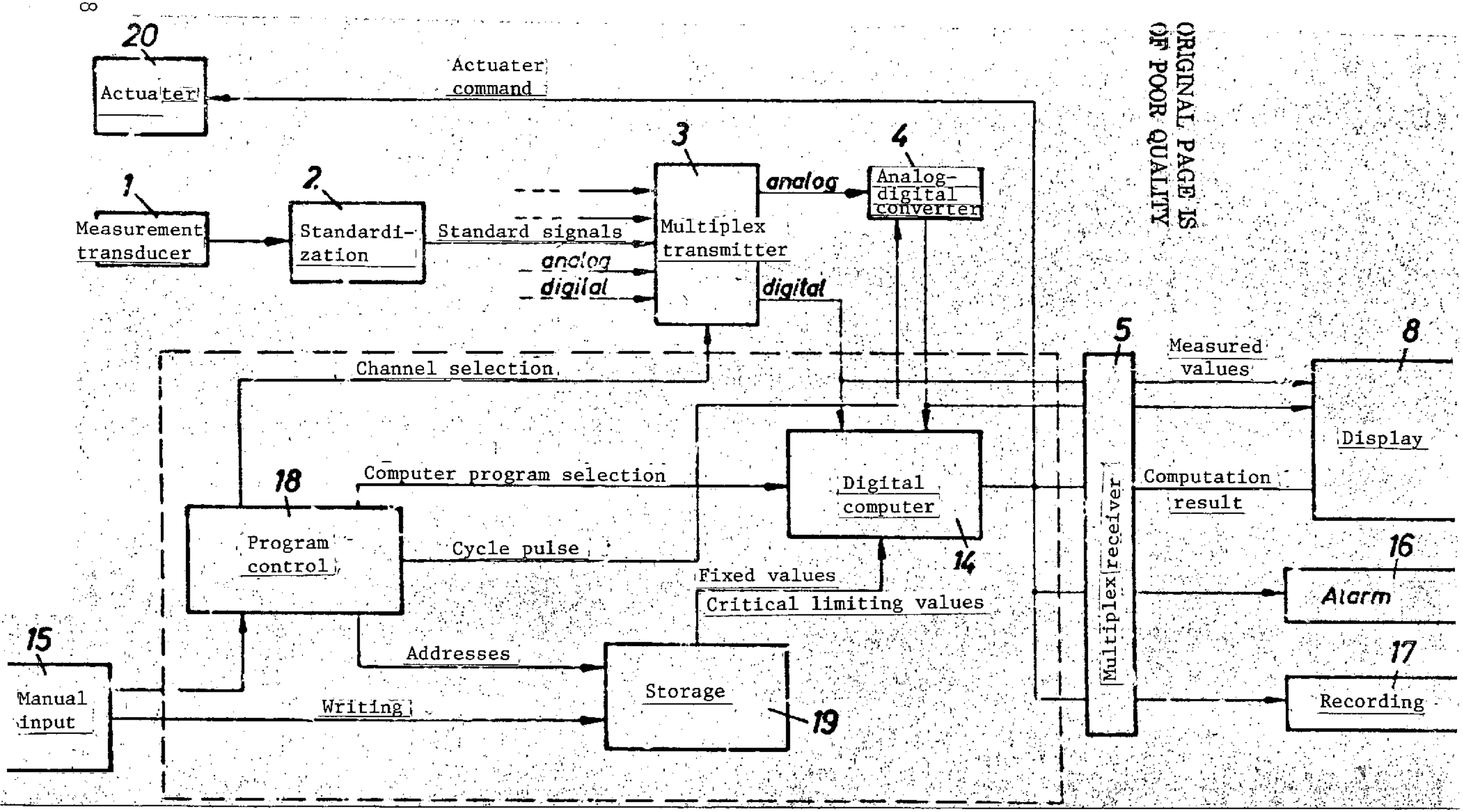
20
Actuater
Actuater command
1
Measurement transducer
2
Standardi-zation
Standard signals
analog
digital
3
Multiplex transmitter
analog
digital
4
Analog-digital converter
Channel selection
5
Measured values
8
Display
Computer program selection
18
Program control
Digital computer
14
Computation result
Multiplex receiver
Cycle pulse
Fixed values
Critical limiting values
16
Alarm
15
Manual input
Addresses
Storage
19
Writing
17
Recording

Figure 2

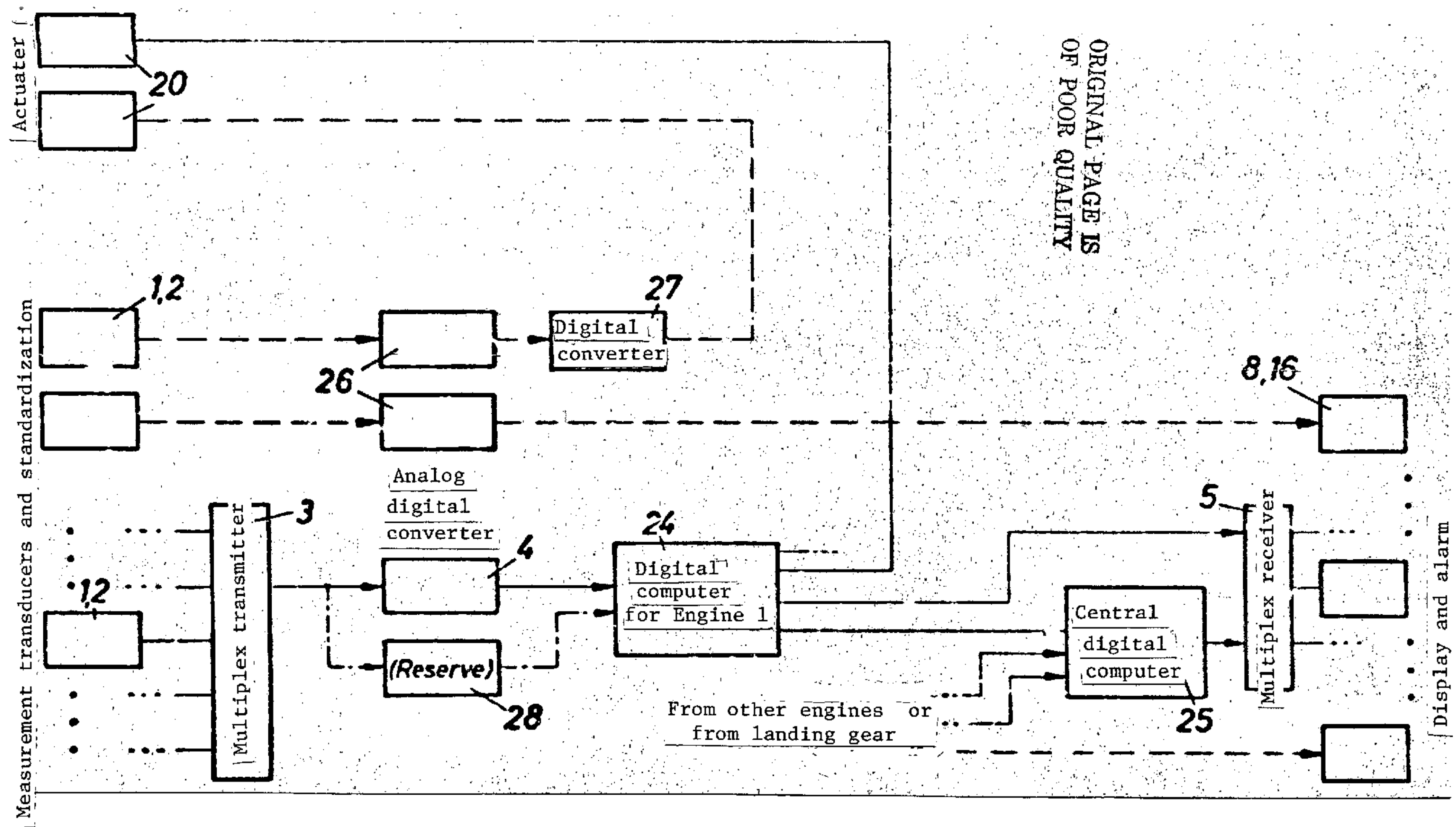
Actuater
20
20
Measurement transducers and standardization
1,2
26
Digital converter
27
8,16
Analog digital converter
3
Multiplex transmitter
4
24
Digital computer for Engine 1
1,2
(Reserve)
28
5
Multiplex receiver
Central digital computer
25
From other engines or from landing gear
Display and alarm

Figure 3